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THE INTERACTION BETWEEN THE INDOOR ENVIRONMENT AND BUILDING CONSTRUCTION

The project listed in the acknowledgment focused on monitoring the occurrence of various fungus genera within building constructions of residential, non-residential and historic buildings. Fungoid organisms found on indoor surface of building constructions are a serious aesthetic and constructional/structural disadvantage with enormous impact on the interior environment of exploitable space. They can be found not only in rooms of old buildings, but also in newly built or reconstructed areas, where one would not expect them. Greater amounts of fungoid organisms occurring in artificial environments are harmful to humans. Therefore professional information provided to the public concerning their harmful impact not only on construction materials, but also on human health is very necessary.

Keywords: historic buildings, incorrect utilization, mildew, air contamination, air sampling, biological factors, indoor environment, fungoid organisms

1. THE SCOPE

Based on the mentioned facts and on the perspectives/outlooks of broadened utilization of the existing areas we had set up a goal, during transitional and winter period to carry out continuous test measurements of thermal-technical parameters of outer constructions and the measurements of factors affecting the highest acceptable levels of harmful factors in indoor air in implemented ground-floor areas of the selected historic(al) object/building after its partial reconstruction.

2. OBJECT OF MEASUREMENTS

The object of measurements consisted of a part of Pensioners' Home and of the Home of Social Services situated on the periphery of the historical area, in the centre of Kosice city on the Southern Avenue No. 2. This area is the historical cultural heritage registered in the Central List of Historical Heritage Fund as item No. 1133/1. The institute includes altogether 5 objects - the main object (northern and southern part), annex building to kitchen's rear, workshop, garage and morgue. Further, two inner courtyards and park belong to the area. This area is referred to as the city hospital (xenodochium) already in the Middle Ages. However, today no medieval parts of the building are known. It is a building which was constructed

in many phases, while its overall appearance is baroque-classicistic. Today the premises consist of the church of the Holy Spirit in the centre, with two U-shaped wings to the north and to the south creating two inner courtyards. The object as a unit has one underground and three over ground storeys. The entire object had been built by traditional masonry technology with bricked vaults. From the point of view of taking care for historical monuments priorities include the masses themselves of the building on the eastern side, and further the rear view on the church nave. In the interior from the point of view of taking care of historical monuments, valuable parts are the vaults, the pavements, coating of stairs made of noble stone from pre-war period, the decoration of the southern passage and naturally the conception of disposition and of the inner spaces in the oldest parts of the building. The survey of the object revealed many places (practically in all open areas of the first over ground storey) with tracks of intense in-leakage of water through peripheral constructions (mainly the ceiling), some places including biological stains (mildew) and deteriorated coating. As the object of test measurements of physical parameters affecting the creation of mildew, rooms at the thermal area A were selected. Office rooms selected for test measurements were situated on the first over ground storey - the ground floor (Fig. 1). The differences between measured rooms lay in the orientation, the manager's office with northern orientation (room No. 115) and the kitchen office with eastern orientation (room No. 132).

Fig. 1. Views of the Pensioners Home premises with marked position of rooms No. 115 and 132

3. MEASUREMENT METHODS

According to the act of the National Council No. 272/1994 Coll. [1] the indoor air in residential and non-residential buildings designed for long-time presence of people may not represent risk of health deterioration due to presence of physical, chemical, biological and other harmful factors. The highest acceptable values of harmful factors in the indoor of buildings are revised for each contamination. For mildew spore occurrence in the air the highest acceptable biological factors' concentrations for air contamination of buildings are as follows (see Tab. 1).

Table 1. **Category of building atmosphere contamination**

Category of building atmosphere contamination	The highest acceptable concentration [CFU/m^3]	Comment
Very low contamination	≤ 25	The mildew concentration in the atmosphere of buildings must not exceed 500 CFU/m^3 of air
Low contamination	26÷100	
Middle level contamination	101÷500	
High contamination	501÷2000	
Very high contamination	≥ 2001	
Visible mildew growth	0	

Table 2. **Generally, the basic condition of mildew growth and development can be summed as the following [2]**

humidity	optimum material humidity α_w = 0.8÷0.9, optimum air humidity 80÷90% (for some species even 60% is enough)
temperature	optimum is 18÷28°C, occurrence is possible in the range 0÷60°C depending on the mildew species
nutrients	carbon and nitrogen of various origin (protein, sugar etc.), minerals
light	is not necessary
pH value	environment mildly acidic to neutral, optimum pH value is 5÷7 depending on the mildew species
oxygen	necessary

In the assessed interior of selected offices rather high occurrence of mildew was found (Fig. 2). For the basic survey of the ground floor "in situ" we only used visual diagnostics, while the following were carried out in these selected rooms:

- measurement of indoor climate parameters aimed at determination of mildew occurrence conditions
- measurement of indoor surface temperatures of constructions with mildew occurrence
- determination of indoor air contamination by mildew spore given in colony forming unit per cubic metre [CFU/m^3].

The surface temperature measurements of individual peripheral constructions were proposed in order to monitor locations of building constructions (with different surface temperature) with mildew occurrence.

Table 3. **The positions of temperature sensors**

Description	Measured value	Position on the building construction
K21	indoor surface temperature	indoor supporting wall
K22	indoor surface temperature	outer peripheral wall

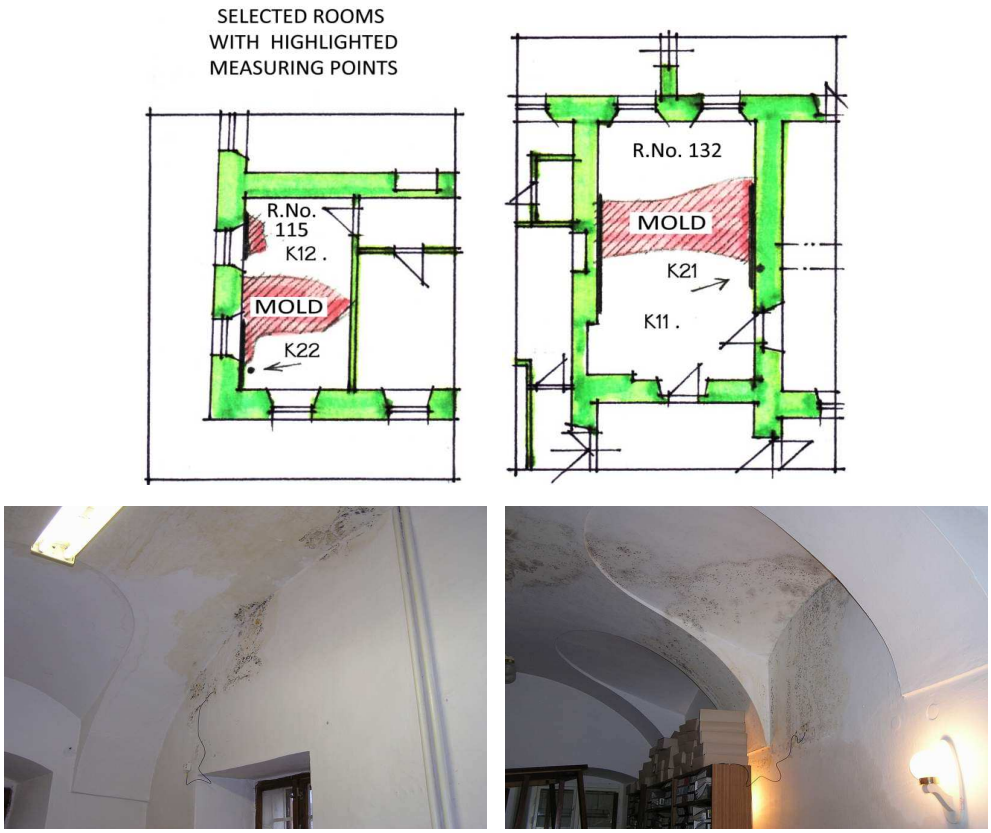

Fig. 2. Views of mildew occurrence in rooms No. 115 and 132 with positioned sensors

4. RESULTS AND DISCUSSION

In the rooms of the office No. 115 and 132 measurements of indoor air temperature and relative humidity were carried out. The measurements were done in non-stationary conditions at the end of the transitional period, during object exploitation in duration of 14 days (since 4 November till 18 November). The measured data were recorded in half-hour intervals. The outdoor air temperature in this period lay between 0 and 16.4°C (the average 8.0°C).

Indoor air temperature and relative humidity measurements, as well as outdoor air temperature measurements data, are shown in Figures 3 and 5. In both cases we can conclude that direct in-leakage of rain water into the construction is the primary source of humidity. The gradual decrease of relative humidity seen in Figures 3 and 5 was caused by the process of drying (combination of heating and ventilation of rooms). In the room of manager's office this trend is distinct. Less distinct is the decrease in the room of the kitchen office caused by additional source of humidity - work in the kitchen with insufficient ventilation for exhaust of humidity from the kitchen working place.

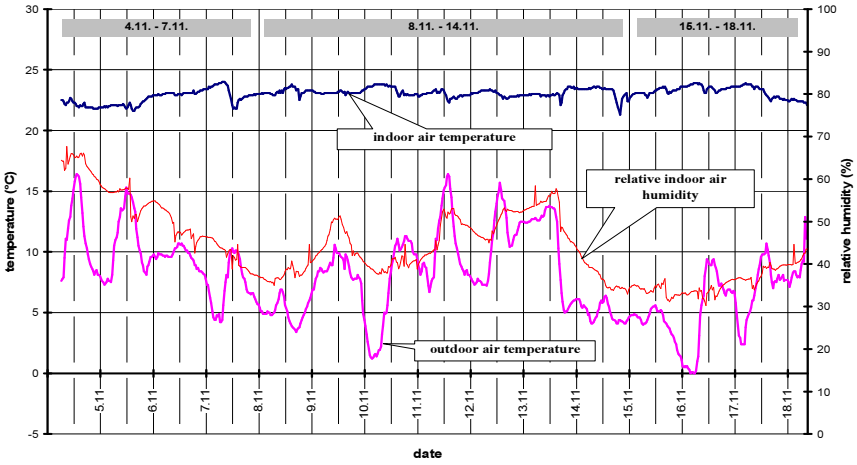

Fig. 3. Temperature and relative humidity of the indoor air in the room of manager's office and outside air temperature changes during measurement

During the measurements in non-stationary conditions, in the room of manager's office at the investigated place (measurement of surface temperature) with the given temperature-humidity state of the indoor environment air, neither preconditions for surface condensation nor preconditions for mildew occurrence on the indoor surface of the construction were created. The values of indoor surface temperatures are significantly above the calculated critical temperature for mildew occurrence and the dew point temperature, see Figure 4.

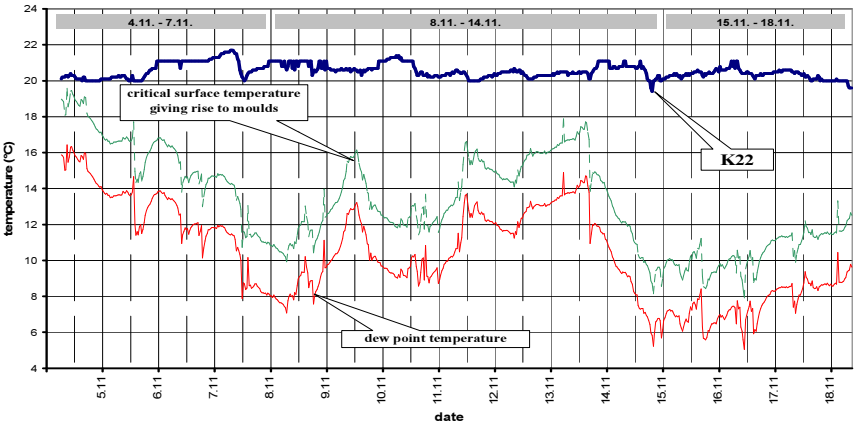

Fig. 4. The changes of indoor surface temperature in the upper part of the peripheral wall in the manager's office compared to the critical temperature of mildew occurrence and to the dew point temperature

The growth of mildew on indoor surfaces was caused by rain water soaking into the construction - by wet material. In the kitchen office during measurement of surface temperature under non-stationary conditions with given temperature-humidity state of the indoor air, preconditions for surface condensation were not created.

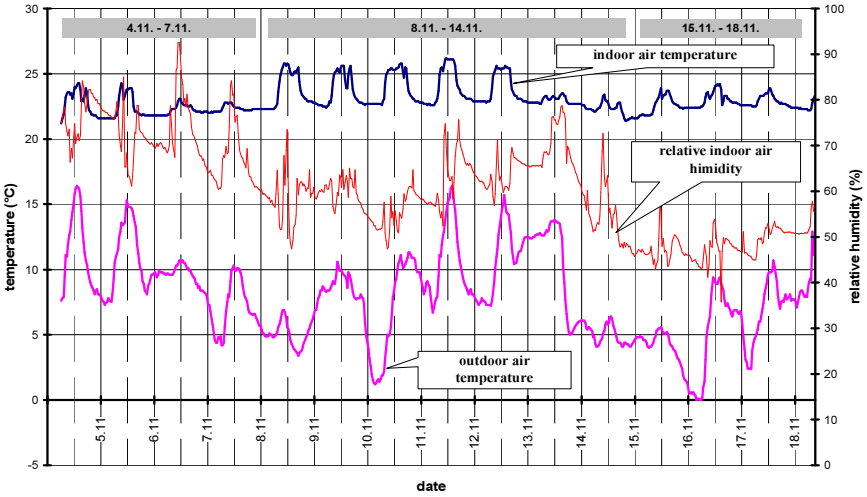

Fig. 5. Changes of indoor atmosphere temperature and relative humidity in the kitchen office and of the outside atmosphere temperature during the measurements

In some cases (5.5% of measurements) conditions for mildew growth were created at the temperature-humidity state, when the temperature decreased below the critical temperature of mildew occurrence, see Figure 6. Mildew on the inner surface occurred as a result of combination of relative humidity and the indoor atmosphere's temperature. Drying the building construction in this room was rather difficult, because the work in the kitchen without appropriate ventilation represented a significant source of humidity.

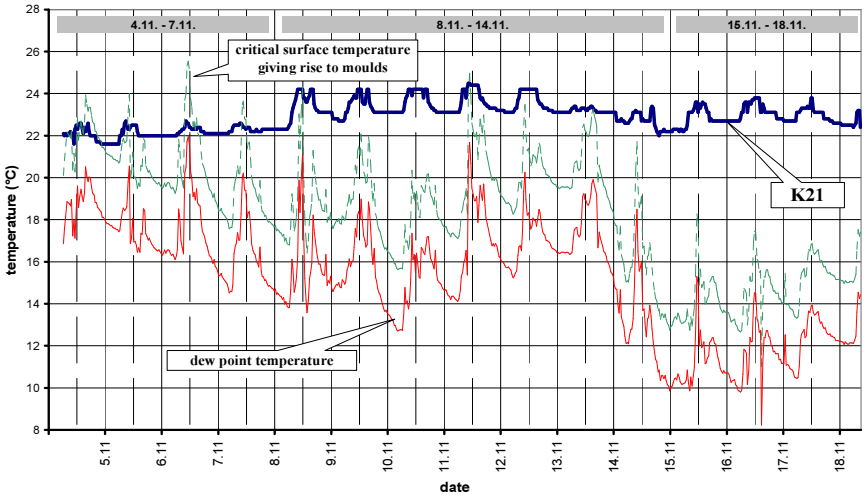

Fig. 6. Changes of indoor surface temperature in the upper part of kitchen office inner wall compared to the critical temperature of mildew occurrence and the dew point temperature

From the long-term point of view the relative humidity decreased already during the measurements and in the period since 15 November the surface temperature has not decreased below the critical temperature of mildew occurrence. For the measurement of the air contamination by mildew spore a Button^{TM} Aerosol Sampler using gel filters combined with an Air check Sampler pump were used.

After eight hours long sampling the degree of indoor atmosphere contamination was determined from a specimen in cooperation with the Institute of Microbiology and Immunology of the University of Veterinary Medicine in Kosice. The final value of spore contamination of the indoor atmosphere was 2061 CFU/m^3; according to the Table 1 this value means a very high degree of contamination.

CONCLUSION

The primary reason for mildew occurrence on the indoor surfaces in the examined rooms is the soaking of constructions resulted from in-leakage of rain water during the reconstruction works on the roof. The apt degree of dampness in the construction material created the preconditions for growth and development of mildew on the indoor surfaces. By gradual drying of constructions and with apt combination of room overheating and ventilation the conditions good for mildew growth will be eliminated. After stopping the in-leakage of water, apt handling of surfaces aimed at mildew removal and proper usage of the inner rooms with respect to temperature-humidity mode, further occurrence and spreading of mildew can be prevented.

Acknowledgements

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ODDZIAŁYWANIE POMIĘDZY ŚRODOWISKIEM ZEWNĘTRZNYM A KONSTRUKCJĄ BUDYNKU

Celem projektu jest monitorowanie występowania różnych rodzajów grzybów wewnątrz konstrukcji budynków mieszkalnych, niemieszkalnych oraz zabytkowych. Grzyby znajdowane na wewnętrznej powierzchni konstrukcji budowlanych w swojej najprostszej postaci jako pleśń są poważną estetyczną i konstrukcyjno-strukturalną wadą z ogromnym wpływem na jakość środowiska wnętrz. Można je znaleźć nie tylko w pomieszczeniach starych budynków, ale również w nowo budowanych lub przebudowywanych obiektach, gdzie nie powinny występować. Duża ilość grzybów obserwowana w sztucznie stworzonym środowisku w pomieszczeniach jest szkodliwa dla ludzi. Dlatego też profesjonalne informacje podane do publicznej wiadomości, dotyczące ich szkodliwego wpływu nie tylko na materiały budowlane, ale także na zdrowie ludzi, są bardzo potrzebne.

Słowa kluczowe: budynki historyczne, nieprawidłowa eksploatacja, pleśń, zanieczyszczenie powietrza, pobieranie próbek powietrza, czynniki biologiczne, środowisko wewnętrzne, grzyby